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DISTURBANCE OF THE ATTENTION DURING SIMPLE MENTAL PROCESSES.

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The purpose of the present investigation was to test the accuracy of earlier experiments and to throw new light on some aspects of the subject. The experiments were made in the laboratory of Professor Ebbinghaus, in Berlin, beginning in May, 1890, and extending to February, 1891. The laboratory consists of a single room; this made it impossible for the reactor and the one who conducted the experiments to be separated. There was no conversation, however, during the progress of the experiments, except as the reactor said "worthless" when some abnormal conditions made the value of a certain reaction doubtful. The work was carried on late in the afternoon and in the evening, when the surroundings were quiet. A signal always preceded the excitation by about three fourths of a second.

A Hipp chronoscope of the new pattern was used. Its accuracy was tested regularly. The description is given in Wundt's Psychologie.[1] The reactor was George A. Coe, Ph. D., an American, who kindly lent his assistance to my investigations, and to whom I am indebted for many valuable suggestions.

The sound which served as the excitation for the simple muscular reactions was caused by the striking together of two weights. Each weight was connected with the circuit in such a way that when they touched one another the circuit was closed. This sound called for a response with the first finger. The striking together of the same weights gave one of the sounds when a choice between two movements was to be made. The first and second fingers of the right hand were used in reacting. The key-board consisted of five keys connected in the usual way. The sound of the weights was

[1] 3d. ed. p. 275 VII.

responded to with the first finger, by the pressure of which, upon the key, the current was broken and the chronoscope stopped.

The other sound was produced by the dropping of a ball from the arms of a Hipp fall apparatus.[1] The moment the ball reached the board below the electrical current was closed and the chronoscope started. The muscles of the arm and hand were tense, ready for action, and the attention closely concentrated on the movement to be made. As soon as possible after hearing the sound, the reactor would break the current by pressing a key.

The preliminary experiments suggested other questions, which stood in such close relation to the ones at issue that their investigation seemed desirable. It has been thought best to first introduce some of these experiments, which really came later in the series, as in many cases they have a bearing on the others.

For some time I have been convinced that it is a wrong method to take reactions of one or possibly two kinds, on certain days, and finish those of one sort before beginning the others. Reactions whose results are to be placed in immediate comparison with one another should be taken on the same days, and the order of succession of the different kinds should be changed from day to day, so that the disturbing influences of weariness, practice, and other less easily controlled conditions, may, so far as possible, be eliminated or equalized.

In some of the earlier experiments which I made, in which a choice between two movements was necessary, the reactors said that they found themselves at times involuntarily "guessing" which of the two sounds would come next, and they thought that the reaction followed much more quickly sometimes, on account of their correct conjecture. J. V. Kries[2] has already called attention to the fact that a reaction will follow more or less quickly according as a presentation of the movement to be carried out is already in the mind or not. In order that this might be tested, two series of experiments were made, which I will call the "chance" and "non-chance" series. In the "chance" series the succession of the two sounds which served as excitations, and to each of which a particular movement responded, was previously determined by tossing of a copper coin. In the "non-chance" series I followed the dictates of my mind in the succession, but made every possible effort to keep the order uncertain.

[1] Wundt's Psychologie, 3d ed. II. 275.

[2] Vinteljahrschrift für Wissenschaptliche Phil. 1887 II. 4.

The experiments were performed according to the plan mentioned above. Some of each of the two kinds were taken every day, and those that came first one day would come last the next. In this way it was hoped to equalize many disturbing and uncertain elements.

A high card-board partition separated Dr. Coe and myself. It was thus impossible for him to receive any suggestions from such movements as I might make.

Table I. shows the results of the first set. The purpose was to determine the difference between the "chance" and

TABLE I.

Date.	Reaction[1] in Chance Series.	M. V.[2]	Number of Experiments.	Reaction[1] in Non-chance Series.	M. V.[2]	Number of Experiments.
1890.						
Nov. 17	218	30	23	193	35	38
" 18	230	29	45	198	33	53
" 19	204	29	49	206	21	51
" 20	210	22	49	209	30	61
" 21	205	25	39	216	24	37
" 21	204	21	18	188	19	22
" 22	203	33	27	197	23	28
" 22	198	23	26	193	26	34
" 24	210	18	25	193	26	34
" 25	166	19	31	169	21	34
" 25	185	31	31	169	21	35
" 26	175	20	30	188	25	31
" 27	177	28	31	169	27	37
" 28	187	32	30	167	18	33
" 28	176	26	29	160	17	33
" 29	170	22	30	160	25	34
	195	25		186	24	

[1] The figures denote $\sigma = 0.001$ sec.

[2] M. V. = mean variation.

"non-chance" method. Sixteen averages, gained from a varying number of trials, are given in each series, and in nine of these the "chance" series is markedly longer than the "non-chance." In two cases the "chance" is less than the "non-chance," and in five the two are so nearly equal as to be considered practically the same. In three of these the excess, though slight, is still in favor of the "chance" series. The average difference is 9 σ.

The reactor did not know the order of the two series, but he always "felt" a difference in them. Each day at the close of the evening's work he would guess which had been the chance series, forming his opinion from the feeling of greater ease which was associated with the one or the other series, and almost without exception his judgment was correct.

A doubt, however, suggested itself. Perhaps Dr. Coe's knowledge of the problem to be solved unconsciously influenced his reactions. That this might be tested I asked Mr. Mulfinger, also an American, to react for a few days. Mr. Mulfinger had gained experience in reacting during the previous semester, but knew nothing whatever of the question at issue until all the experiments had been completed. The result of 100 experiments in each series was as follows: reaction-time for the chance series 193σ, with a mean variation of 29σ, and for the non-chance series 168σ, with a mean variation of 23σ. Mr. Mulfinger also felt less difficulty in responding to the "non-chance" series, though he had no knowledge whatever regarding the object of the experiments or the difference between the series.

The inference from these experiments is clear. The mind of the experimenter works according to certain laws of regularity which he cannot escape. This regularity will assert itself in the way in which he chooses between the two stimuli and in time may disclose itself to the other mind, though the latter is conscious of it only through a vague feeling. Had I not tried to make the non-chance order perplexing to the reactor, the difference between the two series might have been still greater, as the mind would then have been free to follow its inclination.

In both of the preceding cases the number of single experiments made at one sitting varied from twenty to sixty. The difference of the two kinds was not found when the experiments were made in short series of 9 to 16, the averages being practically the same. A little time seems to be necessary before the reactor's mind can become master of the law of regularity which the other unconsciously follows.

It seems probable, therefore, from the results of these investigations that all experiments in which a choice is involved

should be made either in a chance order or the number of successive trials should be limited to ten or twelve. Otherwise the law of regularity of the mind will betray itself in the order of succession and the results will contain a constant error. In all of the following experiments in which a choice forms a part, I have followed a chance order, determined as before by the tossing of a coin. This was necessary in investigations of this nature because the stopping of the work at the end of twelve trials would have kept the reactor's mind in a constant state of unnatural excitement. The importance of this will be seen when we reach the experiments that test the influence of different grades of disturbance.

We now turn to the first set of experiments to show the effect of a disturbance on the reaction-time. These preceded the experiments given in Table I., as will be seen from the dates, but as they do not involve a choice the question of chance does not affect them.

It is evident that when a question of a disturbance of the attention is being investigated, great care must be taken in rejecting figures. When the numbers to be discarded are judiciously selected the results can be made to support almost any previously acquired theory. For this reason I have rejected few figures and seldom when the reactor did not himself say immediately after reacting that some unusual disturbance had made the reaction valueless. In the other few cases where a figure was rejected, it varied so much from any of the others as to leave no doubt of its worthlessness.

The arrangement of the apparatus was the same as before. The large card-board partition kept the reaction free from such disturbances as might otherwise have influenced his reactions.

The following set consists of two series, the simple muscular reaction[1] in response to an excitation of the sense of hearing and the same taken while a metronome was ticking one hundred and twenty times each minute. Not only were some of both series taken every day, but the order in which they were taken was also alternated, so that on one day the simple muscular reaction preceded the muscular reaction with the disturbance, while on the next day the order was reversed.

As the result of 100 experiments in each series made under exactly similar conditions, the simple muscular reaction-time was 103σ, with a mean variation of 9σ, whereas the reaction-time, with disturbance of the attention by the ticking of the metronome, was 122σ, with a mean variation of 12σ, the atten-

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[1] WUNDT, *Physiologische Psychologie*, II. 265, Leipzig 1887.

tion being given to the movement to be made. The lengthening due to the disturbance is 19σ.

It would seem that the ordinary muscular-reactions are affected by a disturbing sound. Obersteiner's investigations[1] have already supported this view, but his method was hardly satisfactory. The playing of a music box served as his disturbance and the reaction-time under these conditions was learned. That the time required when the attention was undisturbed might also be found, the playing occasionally ceased just before the excitation was given. The sudden stopping of a sound would tend to startle the reactors and the reaction following would hardly be reliable.

Cattell claimed[2] that the reason why some earlier investigators found the reaction time lengthened by a disturbing sound was probably due to the fact that the reactors had not learned to make their reactions automatic. It can hardly be considered as yet fully settled that the muscular reactions are strictly automatic, if by this he means purely brain reflex. This has lately been made doubtful by the investigations of Dr. Götz Martius[3]. Dr. Coe, whose reactions are given in Table IV., had reacted from the beginning according to the so-called muscular method, and his instructions during these experiments were to keep his muscles innervated and his attention strictly on the movement to be carried out. No attention whatever was to be given the disturbance and the reaction was to follow the excitation as quickly as possible. Wundt in the third edition of his *Physiologische Psychologie*, II. 290, supports Cattell's opinion.

In view of these results I am unable to agree in the opinion that muscular reactions are not lengthened by disturbing sounds. The separate averages are fairly regular and in every case the muscular reactions taken during the disturbances are longer than the others. The final average, gained in each case from one hundred trials, gives a difference of 18σ between the simple muscular reaction without disturbance and the same kind of reaction taken while the attention was disturbed.

In connection with these results it may be interesting to notice some others that differ only in one respect. In the experiments which we have just considered the attention was directed as closely as possible to the movement. In the next set it was given to the ticking of the metronome.

Some of the muscular reactions without a disturbance were also taken each day in connection with the others in order to gain a reliable basis of comparison.

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[1]Brain, 1879, I. 447.
[2]Philosoph. Studien III. 329.
[3]Philosoph. Studien VI. 167.

With the attention fixed upon the disturbing sound the result of 50 experiments without disturbance and 100 with disturbance, made on three successive days, was 110σ mean variation, 7σ for the simple muscular reaction and 158σ mean variation, 14σ for the reaction with disturbance. The difference due to the disturbance is 48σ.

Comparing these figures with those obtained when the attention was directed toward the reacting finger, we find that the difference between the time of reaction during a disturbance to which the reactor gave no attention and the time required when the attention was directed to the disturbing sound is 36σ.

Let us now pass to the experiments in which a choice between two movements was necessary. The sounds to which the movements responded were caused in the manner already explained. The first finger of the right hand reacted to the sound of the two weights as they were struck together and the second finger to that of the falling ball.

The disturbing element was the metronome ticking one hundred and twenty times each minute as before.

The results were as follows: Reaction with choice 179σ (mean variation 21σ; 100 experiments); reaction with choice, but with a disturbance, the attention being directed as closely as possible to the association of stimulus and movement, 197σ (mean variation 25σ ; 100 experiments) ; reaction with choice, but with a disturbance, the attention being directed to the disturbance, 265σ (mean variation 27σ; 100 experiments). The lengthening due to the disturbance is 26σ in the first case and 86σ in the second.

If these results be compared with the simple reactions given above, it will be noticed that, unless a choice is involved, a disturbance has much the same effect as in the simple reactions, provided the attention is directed in the one case to the correspondence of movement and sound and in the other to the movement itself. The increase is 19σ in each case.

When the attention is given to the disturbing sound, however, the lengthening of the time is much more marked in the choice series. This is not surprising, because the attention, after turning from the disturbances to the reaction, would lose more time in associating the given excitation with the corresponding movement than in making a single movement already determined. The lengthening is 48σ for the simple reaction as contrasted with 86σ for the choice-reaction.

It is interesting to observe that while the mean variation increases somewhat under the influence of a disturbance, nevertheless the increase is not very great.

During the progress of these experiments the possibility of

distinguishing a little more closely between disturbances suggested itself. The mind seems at times more in unison with certain disturbing sounds than with others. Is it not possible that this will show itself in the reactions? If this is true, clearly we will have no right in the future to speak simply of a "disturbance of the attention," but must first measure its effect in comparison with other disturbances of the same kind, but differing in intensity. In order that this might be tested we arranged a set of experiments with a graded disturbance.

The excitation consisted as before of the two sounds and the response was given with the first and second fingers of the right hand. Five series were taken and the metronome ticked 40, 80, 120, 160 and 200 times each minute in the respective series. Each contained one hundred trials; the only exception is the series with 120 beats, which contained ninety trials. As before, some of each were taken every day and the order was always changed.

The results are shown in the following table:

TABLE II.

Number of ticks.	40	M V.	80	M V.	120	M V.	160	M V.	200	M V.
Dec. 11	201	14	218	15	185	20	202	23	200	19
" "	213	20	198	19			204	13	217	15
" 12	223	33	200	25	185	19	221	18	211	14
" "	210	13	215	32	188	18	215	16	232	25
" "									208	16
" 13	206	22	206	21	202	19	197	20	190	16
" "	203	20	227	14	202	22	194	15	197	17
" 15	199	13	204	11	188	13	197	18	198	14
" "	208	17	211	25	185	12	203	31	200	19
" 16	203	13	210	8	184	28	224	21	205	17
" "	198	13	213	17	204	19	221	15		
Average	206	18	210	19	191	18	208	19	206	17

The experiments were grouped in sets of 10 each in consecutive order; each number in the table thus represents the

average of 10 experiments, the lower line giving the average for the whole hundred.

In almost every case the partial average of the experiments made while the metronome was giving one hundred and twenty sounds each minute is lower than any of the others. In only a few cases is it higher. From the point with one hundred and twenty ticks the reactions are at first longer and then they slightly decrease. It would seem that there is a *point of least disturbance* which may be approximately found by means of the reactions. This point of least disturbance probably differs with different persons. Dr. Coe was not told at what point the metronome was set, though this would partially betray itself in the ticking. The difference found cannot be the result of practice or weariness, as some of each series were taken every day and the order of succession was never the same.

We now turn to the investigations with reference to the sense of sight.

These experiments were carried on during the evenings when it was quite dark. No light was visible except that which at the proper time served as a disturbance. In order that the chronoscope might be read without lighting the room, a small dim lantern was so arranged that a dark paper funnel connected it with the chronoscope.

The light which served as the stimulus was a Geisler tube, through which a current of electricity could be passed. A card-board about three feet high and four feet long was placed upright directly in front of the reactor and at a short distance from him. A large mirror was attached to the front of the card-board and a hole three inches long and one half of an inch wide in the center of the mirror corresponded to a similar one in the card-board. Through this hole the light of the Geisler tube, which was immediately behind the board, could be seen the moment the current passed. When the simple muscular reactions were taken the mirror was not used. For the reactions in which a disturbance was desired the mirror was attached and a tallow candle of the ordinary intensity was placed in such position behind the reactor as to be reflected in the mirror. The hole in the mirror cut the image of the flame so that it was seen above and below the opening.

The first set of experiments consisted of three series: first, the simple muscular reactions in response to a light stimulus; second, the same reactions taken while the reflected light of the candle was flickering across the opening in the mirror and card-board, through which in a moment the light of the Geisler tube would be seen. In the third series an attempt was made to still further disturb the attention by the image of a revolv-

ing card. This card was about ten inches long and six wide and was covered with a few plain figures. It was placed behind the reactor so as to be reflected in the mirror around the opening through which the light of the Geisler tube was expected. A rotating apparatus caused the card to slowly revolve. The candle was used to illuminate the disk. In all three cases glass in front of the Geisler tube colored the light red.

The results are as follows: Simple reaction, 140 σ (mean variation, 11 σ; 40 experiments); simple reaction with disturbance by the candle, 148 σ (mean variation, 10 σ; 50 experiments); simple reaction with disturbance by the revolving card, 139 σ (mean variation, 12 σ; 70 experiments).

The simple muscular reactions of 140 σ is a little less than the results gained by Cattell.[1] The difference is readily understood when we remember that Cattell carried on his investigations during the day, and the sunlight reflected from a white surface would probably require more time to come into the consciousness of the reactor than a red light in a darkened room.

A rather surprising fact is that the simple candle flame flickering across the opening in the mirror, was a source of greater disturbance than the revolving card. The reason of this, however, is not difficult to find. The card, though covered with figures, was too monotonous to serve as a disturbance. This may explain the fact that some investigators have found the reactions so little influenced by a disturbance of the attention. The candle distracted the attention somewhat more, because the reactor looked directly at the flickering flame as it fell across the opening through which he awaited the exciting light. In the other series the eyes were directed rather to the image of the card as it slowly turned. Anything so monotonous will hardly influence the reactions, and still less when the reactor has been told to hold his attention closely to the movement to be made.

The three series differ so little that we can hardly say the reactions were affected, especially when we observe that in the case of the revolving card they are, in fact, less than the simple musculary. The mean variation of the three series is about the same.

From these experiments it was evident that some more positive disturbance must be found.

To accomplish this, I replaced the revolving card with another which was of a circular form, twelve inches in diameter. Around the edge of this disk nine holes were cut.

[1] Philosoph. Studien, III. 324.

These holes were one and two eighths of an inch long, and sloped from seven eighths of an inch at the top to one half of an inch at the bottom. This disk was attached to the rotating apparatus, and the lighted candle was placed behind in such a position that the flame shining through the holes in the disk was reflected in the mirror. The rotating apparatus was thus caused to revolve so that five hundred and forty flashes of light fell upon the eye each minute.

The results were as follows: Simple muscular reaction to light, 143 σ (mean variation, 10 σ; 100 experiments); simple muscular reaction with a disturbance caused by 540 flashes per minute, 171 σ (mean variation, 15 σ; 100 experiments). The lengthening due to the disturbance of the attention is thus 28σ.

The reaction time for a sound sensation has been found above to be 102 σ and 110σ. The time needed to respond to a sight excitation is thus seen to be about 30 σ to 40 σ longer.

While we were engaged in these experiments the thought suggested itself of arranging a series of disturbances for the sight which could be compared with those already used for the sense of hearing. It would then be possible to learn through which of these two senses the attention is more easily disturbed. This has before been impossible because there has been no unit of comparison for the disturbances.

The problem was readily solved by means of revolving disks similar to the one just used. Three disks were prepared. The first had only one hole, which was of the same size and shape as those already described. The second contained two holes, one at each end of a diameter, and the third had one at each of the three corners of an isosceles triangle inscribed within the circular disk. The rotating apparatus was so regulated that it revolved sixty times a minute. It was thus possible with the three disks to give 60, 120 and 180 flashes of light each minute.

The results were: simple muscular reaction in response to a visual stimulus, the attention being disturbed by 60 flashes per minute, 195 σ (mean variation, 14 σ; 120 experiments); with the attention disturbed by 120 flashes, 197 σ (mean variation, 13 σ; 120 experiments); with the attention disturbed by 180 flashes, 190 σ (mean variation, 16 σ; 120 experiments).

The time required by Dr. Coe to react muscularily in response to a light excitation was 143 σ, as seen above. We now find the time increases to 197 σ, with his attention disturbed by 120 flashes of light each minute. We have already learned that the time of reaction for the sense of hearing was 102 σ. In the experiments made on the same day, when the

attention was disturbed by a metronome ticking 120 times a minute, it rose to 122 σ. The lengthening of the time on account of the disturbance was thus 53 σ for the sense of sight, and 19 σ for that of hearing. It is thus seen that when the disturbance and excitation affect the same sense, a distraction of the attention through the sense of sight has more influence upon the reaction time than the same grade of a disturbance through the sense of hearing.

When the effects of the various grades of disturbance are compared, it will be observed that 540 flashes of light a minute are less of a disturbance than 60, 120, or 180 flashes. The probable reason is that 540 flashes acted as a steady accompaniment on account of the rapidity of the flashes. That which is constant tends to be monotonous, and this monotony may have deprived the disturbance of a part of its effectiveness.

Before discussing the experiments undertaken to determine the effect of a disturbance of the attention when a choice was to be made in answer to one of two sight sensations, it will be necessary to describe the apparatus which was constructed for this purpose. The question then was, how to prepare an apparatus by which two different excitations could be quickly and noiselessly produced and the order changed without altering the psychical condition of the reactor. A long lever was fastened to an upright support by means of a pivot, and it was arranged so as to work noiselessly. A light frame, containing red glass above and olive colored glass below, was attached to one end of the lever, which was so placed that this frame was directly behind the aperture in the mirror which we have already described. Through this opening in the mirror the exciting light of the Geisler tube would be seen as the current passed. The other end of the lever extended to the experimenter at the chronoscope, who could raise or lower the handle at pleasure and thus bring the end or olive glass in front of the tube. The change could be made noiselessly in a moment. When the disturbance was desired the mirror was attached, as before, to the front of the card-board, and the disturbing flashes of light were seen reflected around the hole behind which was the Geisler tube. A high partition separated the reactor and the experimenter.

The choice was made in response to the excitations of the colors red and olive. The disk which gave 180 flashes of light each minute was used as the disturbing element. This, it will be remembered, was the "point of least disturbance" for the sense of sight. The final results consist of eleven averages, each of which was gained from ten trials.

The results of the first set of experiments are: Time of

reaction with a choice to be made between two movements in response to one of two different excitations of the sense of sight, 258 σ (mean variation, 23 σ; 110 experiments); time of reaction of the same kind, but with a disturbance of the attention caused by an intermittent light of 180 flashes per minute, 273 σ (mean variation, 25 σ; 110 experiments). This gives a lengthening of 15 σ as the effect of the disturbance.

The influence of the disturbance as shown in the reactions is thus less than for the sense of hearing under the same conditions. When choice was made in response to one of two sounds, the time was 177σ and 197σ, which leaves a difference of 20σ.

We have already noticed that in the simple muscular reactions when the disturbance and excitation are of the same kind, a disturbance through the sense of sight is more effective than through that of hearing. We now find that when the reactions include a choice the mind is less disturbed in discriminating between sight excitations than between those of hearing. The difference, though slight in itself, is so far the reverse of that which we found characteristic of the simple muscular reactions as to deserve attention.

The psychical processes are the same, whether we respond to a sound or a sight excitation and that which makes up an act of choice does not differ with the sense organ excited. The reason why the muscular reactions in response to a light excitation are more influenced by a disturbance through the same sense than those of sound, while in choice the light reactions are less affected, must be sought then in conditions which hasten or retard these processes rather than in the processes themselves. A large part of our knowledge is acquired through the sense of sight. We are constantly called upon to decide quickly between things that we see, seldom between what we hear. We thus gain a facility in discriminating between objects of sight and in acting according to our dicision. This intimate association of sight and movement in choice leads to an ease and rapidity of action which cannot be equaled when the excitation comes to us through another sense.

We are also more familiar with disturbances in our discrimination between objects of sight. In the street many things crowd themselves upon our sight and in the midst of this confusion we are daily called upon to act. It is then not surprising that our more complicated mental processes, when stimulated to action through the sense of sight, are less impeded by disturbances than when the excitation comes to us through another sense. The time of choice in reply to one of two sounds was found to be 176σ, that in response to one of two sights is 258σ.

We have now reached the experiments which may be called the "cross sets." In these the excitation and disturbance affect different senses.

In these experiments the excitation was the usual sound of the two weights. The disturbance was the 60, 120 and 180 flashes of light per minute.

The results were: time of simple muscular reaction in response to an auditory stimulus, 123σ (mean variation 8σ; 80 experiments); muscular reaction to an auditory stimulus, but with a disturbance of the attention produced by 60 flashes of light per minute, 160σ (mean variation 13σ; 100 experiments); same with 120 flashes, 141σ (mean variation 9σ; 100 experiments); same with 180 flashes, 148σ (mean variation 11σ; 100 experiments).

According to my custom I took a series of the simple muscular reactions each day in connection with those accompanied by the disturbance. The result sustains the view that at least a few of the earlier and simpler reactions should be repeated when the more complicated ones are reached, in order that they may serve as a test of the condition of the reactor. The simple muscular reactions average 123σ; the average as given above is 102σ. In both tables the mean variation is small. The reason for this difference in the results is that the shorter time was gained at the end of a long practice when Dr. Coe had reached his maximum rapidity. The others were taken after a period of over two months, during which time experiments of a different kind were being made.

Cattell[1] found that a facility in reacting once gained was not lessened by lack of practice; v. Kries and Auerbach[2] held the same view regarding the simple reactions, but maintained that it is not equally true of the more complicated. I am o the opinion that even in the simple reaction, lack of practice will manifest itself in a lengthening of the reaction time, and that other physical and mental conditons can so far affect the reactor as to make it necessary when accuracy is desired to repeat from time to time the earlier and less complicated tests.

In the results last given we find again that 120 intermittent disturbances each minute is the "point of least disturbance." It will be remembered that this fact has characterized all the results thus far in which the excitation was a sound.

Earlier investigation[4] has led to the belief that the reactions

[1]Philosoph. Studien III. 462-489.

[2]Dubois-Reymond's Archiv 1877, 361.

[3]Dubois-Reymond's Archiv 1877, 362.

[4]WUNDT, Physiologische Psychologie II. 293, Leipzig 1887.

are more influenced through a disturbance of the attention if the excitation and disturbance affect different senses than when both are of the same nature. These experiments do not sustain this view. When the metronome vibrated 120 times each minute, the reaction time for a sound excitation was 19σ longer than without the disturbance. The time required to respond to a light excitation while the attention was disturbed by an intermittent light giving 120 flashes each minute was 53σ longer than when the disturbance was lacking. In both of these cases the disturbance and excitation appealed to the same sense organ. On the other hand we find that when the excitation is a sound and the disturbance a light flashing 120 times a minute, the reaction time is lengthened by only 17σ. Even if we take the point of greatest disturbance, 60 flashes, the average is only 37σ longer than the simple reactions, and this is still much below the 53σ already found to be the difference in time between the simple light reactions and those made under the influence of a disturbance through the same sense-organ.

An analogous set of experiments was now made in which stimulus was visual and the disturbance auditory. In these experiments the excitation was the flash of the Geisler tube seen through the red glass and the disturbance was the ticking of the metronome.

The results were: time of simple muscular reaction in response to a visual stimulus 159σ, (mean variation 10; 100 experiments); same with a disturbance of the attention produced by 60 beats per minute of the metronome 176σ, (mean variation 10; 100 experiments); same with 120 beats 190σ, (mean variation 12σ; 100 experiments); same with 180 beats 174σ (mean variation 11; 100 experiments).

If we take the point of greatest disturbance, which was 120 vibrations of the metronome, the time of reaction is 30σ longer than without a disturbance. This again is much less than the corresponding increase when a light served both as excitation and disturbance.

This lengthening of the time when both the excitation and disturbance affect the sense of sight, cannot have been caused by the disturbing light weakening the excitation, because the exciting light was of sufficient intensity to be clearly seen, even when its appearance and that of the intermittent light were simultaneous. Were this the occasion of the difference it would betray itself in an unusually large mean variation. At times the exciting light would be seen more distinctly and the reaction would follow more promptly. That this is not the case a glance at Table XI. will show. The mean variations are very small, considering that the reactions were made under

the influence of a disturbance. They scarcely differ from those for the sense of hearing as given in Table VI.

Besides, if the more noticeable effect of the light disturbance on the sight reactions is the result of a weakening of the intensity of the excitation, why does not the same peculiarity manifest itself in the choice-reactions for the sense of sight? The same weakening of the intensity would occur in the latter as in the former case. We have found, however, from the results given on page 13 that the time of choice in answer to a sight sensation is 258σ. During the disturbance the reactions average 273σ, an increase of only 15σ, and yet both excitation and disturbance were the same lights that we used in the simple reactions. Though we have found (page 11) that 180 flashes was not the point of greatest disturbance, it would nevertheless make more light and so tend more to weaken the excitation than the 120 flashes, which actually proved a greater disturbance. It is evident, then, that the cause of the difference cannot be found in weakening the intensity of the excitation by the disturbance.

The fact seems to be that in simple muscular reactions an intermittent light is more of a disturbance to the attention than a sound. This has been especially noticeable in the earlier experiments (page 12). If we compare once more the results on pages 14 and 15 we find that both 60 and 180 flashes of light in the "cross sets" proved a source of greater disturbance than the same number of vibrations of the metronome. Here the question of the disturbance weakening the intensity of the excitation cannot even be raised as they affect different senses. Under 120 the sound has the greater influence on the reactions. This average, however, is the largest of the three for the influence of auditory disturbances on visual reactions, and if we place it in comparison with the largest for the influence of visual disturbances on auditory reactions, we find still the light proves the greater disturbance.

It has already been shown that a disturbance of the attention does not have the same effect upon reactions which include a choice as upon the simple muscular reactions. In the latter case we have seen that a disturbance of the attention through sight is more effective in lengthening the reaction time than when the disturbance comes through the sense of hearing. On the other hand, whenever the reaction follows a sight sensation, the time of choice is less affected by disturbances of the attention than if the excitation is a sound. This view is strengthened by two series of experiments on reaction with choice, but with disturbance of the attention.

In the first series of the reactions with choice the excitation consisted of two sounds, produced in the manner described un-

der choice in the earlier experiments. The disks served as the disturbance; they gave 60, 120 and 180 flashes of light each minute.

The results were: time of muscular reaction with choice to one of two auditory stimuli, 230 σ (mean variation, 20 σ; 100 experiments); the same with a disturbance of the attention caused by 60 flashes of light per minute, 267 σ (mean variation, 21 σ; 100 experiments); with 120 flashes, 243 σ (mean variation, 19 σ; 100 experiments); with 180 flashes, 255 σ (mean variation, 18 σ; 100 experiments). This gives a lengthening of 37 σ, 13 σ and 25 σ respectively.

The next series consisted of reactions to sensations of sight, in which a choice between two movements was involved. The attention was disturbed by beats of a metronome.

The results were: time of muscular reaction to visual stimuli with choice, 266 σ (mean variation, 18 σ; 100 experiments); the same with an auditory disturbance of 60 metronome beats per minute, 278 σ (mean variation, 20 σ; 100 experiments); with 120 beats, 267 σ (mean variation, 19 σ; 100 experiments); with 180 beats, 277 σ (mean variation, 17 σ; 100 experiments). The reaction time with choice is thus lengthened to the extent of only 12 σ, 1 σ and 11 σ by the disturbance. Here, as in the previous experiments on sight-reaction with choice disturbed by flashes of light, the time of choice in response to sight excitation is found but little influenced by disturbances. This has been found characteristic of reactions in which a choice is involved. The importance and probable explanation of the fact I have already discussed.

We now turn to several sets of experiments which preceded those which I have thus far given; it has been thought best, however, to introduce them last. In the choice sets the "non-chance" method was used, and it was while engaged in these investigations that the difference between the two methods was noticed.

The purpose of these experiments was to find how the simple "muscular" and the "choice" reactions would vary while the reactor's attention was directed to certain kinds of work. Three tasks were given; 1, repeating a poem already committed to memory; 2, reading an English book; and 3, reading Kant's Kritik der einen Vernunft. The time for the simple muscular and choice reactions under these conditions was learned. The instructions were to fix the attention as closely as possible on the work assigned. I willingly admit that it is impossible to determine how far the instructions are observed in such a case. There are no means by which the amount of attention given to the reaction or to the task can be measured. I am convinced, however, that the direc-

tions were conscientiously followed, partly from my confidence in the reactors and their interest in the investigations, and partly from the fact that at times the reactor failed to respond to the excitation and then excused himself by saying that he was so deeply absorbed in his reading that he did not hear the sound. This occurred while the English book was being read.

The reactors were Prof. A. L. Gillett, of the Hartford Theological Seminary, and Mr. George Mulfinger, also an American. Both of these gentlemen offered valuable suggestions.

The excitation in the four sets was a sound caused in the same way as in the preceding experiments.

The results of the experiments with Mr. Mulfinger were as follows: simple muscular reaction to an auditory stimulus, 102 σ (mean variation, 7 σ; 200 experiments); simple muscular reaction while repeating a poem, 183 σ (mean variation, 23 σ; 200 experiments); simple muscular reaction while reading English, 196 σ (mean variation, 20 σ; 200 experiments); simple muscular reaction while reading Kant, 210 σ (mean variation, 27 σ; 200 experiments). The three distractions of the attention caused a lengthening of 81 σ, 94 σ and 108 σ respectively. When Mr. Mulfinger was required to react after a choice, the results were: reaction with choice, 208 σ (mean variation, 24 σ; 200 experiments); reaction with choice while repeating a poem, 212 σ (mean variation, 24 σ; 200 experiments); reaction with choice while reading English, 216 σ (mean variation, 22 σ; 200 experiments); reaction with choice while reading Kant, 217 σ (mean variation, 27 σ; 200 experiments). The lengthening due to the disturbances was thus 4 σ, 8 σ and 9 σ respectively.

With Prof. Gillett as reactor the results were: simple muscular reaction, 107 σ (mean variation, 6 σ; 250 experiments); simple muscular reaction while repeating a poem, 170 σ (mean variation, 16 σ; 250 experiments); while reading English, 179 σ (mean variation, 17 σ; 250 experiments); while reading Kant, 197 σ (mean variation, 17 σ; 250 experiments). This gives an increase of 63 σ, 72 σ and 90 σ for the three disturbances.

The time of reaction with choice was 235 σ (mean variation, 28 σ; 250 experiments), which increased to 270 σ (mean variation, 31 σ; 250 experiments) while a poem was repeated; to 317 σ (mean variation, 35 σ; 250 experiments) while English was read, and to 357 σ (mean variation, 35 σ; 250 experiments) while Kant was read. We find here a lengthening of 35 σ, 82 σ and 122 σ in the three cases respectively.

The difference here is not so marked. In the first case the increase is in favor of the muscular, and in the other two

with the "choice" reactions. It is clear, however, that the complete separation of the two kinds of reactions by which the muscular are placed beyond the influence of a disturbance of the attention, and regarded as purely practiced brain reflex, while the others only come within the reach of psychical disturbances, cannot be regarded as established. I am led to this conclusion, not alone by these latter experiments, but also by all those preceding. A comparison of results shows a different of only 1 σ in favor of the "choice" reactions on account of the disturbance. This was for a sound excitation, and is practically no difference. If we examine the results, we find a difference of 12 σ in favor of the muscular reactions because of the disturbance, and yet this 171 σ is the least of the effective disturbances that we have found for the sense of sight.